Renewable and Sustainable Energy Reviews 15 (2011) 827–832

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Exploring an integrated approach to utilize indigenous renewable energy to improve energy self-sufficiency and emission reduction

Sufang Zhang *, Liwen Fu

School of Economics and Management, North China Electric Power University, #2 Beinong Road, Zhuxinzhuang Deshengmenwai, Beijing 102206, China

ARTICLE INFO

Article history:
Received 12 May 2010
Accepted 9 September 2010

Keywords:
Indigenous renewable energy
Energy self-sufficiency
Emission reduction

ABSTRACT

This paper explores an integrated approach to utilize indigenous renewable energy to improve energy self-sufficiency and emission reduction in the rural households of Guangxi province in China. A simple cost-benefit simulation model is constructed to (i) analyze the financial and environmental cost under the present rural consumption structure; (ii) analyze the economic and environmental cost and benefits of utilizing rural renewable energy. Recommendations for scaling up utilization of rural renewable energy are also made. The results of the study are: rural renewable energy and energy efficiency can provide both economic and environmental benefits. But as they require higher up-front investment than conventional energy sources, public support and policy incentives should be provided and financing mechanism should be innovated.

Contents

1. Introduction

Rural household energy consumption in China accounts for about 16.7% of the country's disposable energy consumption. Since it is difficult to obtain commodity energy in the vast rural areas, more than 66.7% of rural residents' energy for daily life depends on traditional biomass energy such as straw, firewood, dung, etc., thus leading to an excessive consumption of biomass energy and causing serious soil erosion, ecological environmental disruption and the decrease of organic substances in the soil. It is therefore well recognized that there is an urgent need to improve rural energy self-sufficiency and emission reduction.

China stands at the forefront of developing-country governments that have recognized the need to provide improved energy

* Corresponding author. Tel.: +86 1013552847009; fax: +86 10 80796904.
E-mail address: zsf69826313@sina.com.cn (S. Zhang).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2010.09.016

Table 1
Energy consumption structure of rural households in Guangxi in 2010.

	Straw (%)	Firewood (%)	Coal (%)	Electricity (%)	Biogas (%)	LPG (%)
Cooking	70	41	53	6	90	100
Water heating	11	27	7	9	10	0
Lighting	0	0	0	40	0	0
Space heating	19	32	40	0	0	0
Home appliances	0	0	0	45	0	0
Total	100	100	100	100	100	100

supplies to rural populations. However, this task has proven difficult because poor rural populations cannot afford expensive forms of energy,[1] [1] and the logistics of supplying rural areas are difficult, increasing energy costs. Indigenous renewable energy, however, can be a cost-effective and sustainable electricity supply and can thus reduce energy expenses of rural households [2]. Moreover, the use of indigenous renewable energy such as biogas digesters can help to improve health and to proportional reductions in medical expenditure [5]. All these in turn will contribute to the poverty alleviation of rural households.

Besides, studies have shown that utilizing indigenous renewable energy can control pollutions and protect environment in rural areas to a great extent [3,4]. For instance, a study found that between 1996 and 2003, the annual average output of rural household biogas in China was 2,554,796.95 thousand cubic meters, equivalent to 1824.1 thousand tons of standard coal. The output of biogas every year completely substituted for straw, firewood and coal as the energy for rural family's daily life, which led the annual average quantity of CO_2 emission reduction to be 397.6–4193.9 thousand ton and that of SO_2 emission reduction to be 17.3–62.0 thousand ton [6].

This paper explores an integrated approach to utilize indigenous renewable energy to improve energy self-sufficiency and emission reduction in the rural households in Guangxi, a province in southwest China. A simple cost-benefit simulation model is constructed to (i) analyze the financial and environmental cost under the present rural consumption structure; (ii) analyze the economic and environmental cost and benefits of utilizing rural renewable energy. Meanwhile, issues regarding scaling up utilization of rural renewable energy are also examined.

2. Assessment of rural energy consumption

Referring to rural energy consumption, there are generally two categories of energy users in rural areas, i.e., production energy consumption involving energy for agricultural productions and rural enterprises, and households' energy consumption referring to residential uses for cooking, heating, lighting, home appliance, and also means of family transport in a few cases. The issue we are going to address is the energy consumption of rural households.

2.1. Current energy demand and supply structure of rural households

There is very limited household-level energy consumption data available in China. A few rural household surveys, however, were found in some studies [11–13]. Yutaka Tonooka of Saitama University, et al. [13] undertook a survey of more than 200 households in the rural fringe of Xian during the winter of 2003/2004. Wang, X. [7] of Nanjing Agricultural University surveyed 12 villages and four towns in Sheyang County in Jiangsu Province and investigated data from 384 households. Smith et al. of LBL in California Barkley and Zhao et al. of Renmin University of China undertook a questionnaire survey of energy consumption in rural households and its dose response to human health in three rural areas in China. Guozhu Li of Lanzhou University, et al. [8] surveyed 13 villages in Qin'an and Tongwei Counties, interviewing more than 400 rural households in July 2006. Specific energy demand and supply structure of rural households in each of the surveyed area was reported in these studies.

The above mentioned studies show that household energy use and demand vary widely across provinces in China, especially at the rural level. Local fuel availability is a major factor in the fuel choices. For example, hilly areas used more biomass; plains more electricity, coal and LPG likely due to more easily accessible distribution networks. Climate is also an important factor in fuel use, especially with regard to the amount used for heating.

However, in general, rural household energy use in recent years mainly includes cooking, water heating, keeping warm, lighting, as well as home appliances (TV, music equipment, video recorders, washing machines, etc.). The types of existing energy sources are straw, firewood (wood fuel), fire grass, crop straw, animal dung, coal, electricity, solar energy, LPG and biogas transformed from biomass. According to China Energy Statistics Yearbook 2008, the energy supply structures of China's rural households in 2007 were as follows: straw (49%), firewood (28%), coal (28%), electricity (5%), biogas (2%) and LPG (2%).

2.2. Financial costs of energy consumption of rural households

In order to gauge the financial costs of energy consumption of rural households in Guangxi, a province in southwest China under the present condition of energy consumption structure, a model is constructed below. The financial costs of rural energy consumption are not only linked to the quantity of energy use, but also to the energy utilization structure. When different kinds of energy are consumed, there are large differences among their costs and convenience. Suppose that there are n kinds of energy resources, *m* kinds of energy consumption in a certain region, and x_{ij} is the amount of the *ith* type of resource to use for the *jth* type of purpose (in coal equivalents), c_i is the unit price of the *ith* kind of energy source, namely, the coefficient of financial cost, then the total financial cost of energy consumption in a rural household *Tc* is given as:

$$Tc = \sum_{j}^{m}\sum_{i}^{n} c_i x_{ij} \quad (1 = 1, 2, \ldots n, \;\; j = 1, 2, \ldots m) \qquad (1)$$

We suppose the energy consumption structure of the rural households in 2010 in Guangxi as follows (see Table 1).

The result of financial costs of energy consumption of rural households is obtained when the following assumptions and parameters are taken:

(1) There are 5 persons in each rural household and the average energy consumption per year per household is 3098.95 kgce in 2010. (*Note*: In 2006 the average commercial energy consump-

[1] At the end of 2008, 47.07 million people in China (among which 2.34 million people in Guangxi) were still being trapped in poverty; many of these poor people are living in rural areas.

Table 2
Average consumption of energy sources for different purposes in rural households.

	Straw (kg)	Firewood (kg)	Coal (kg)	Electricity (kWh)	Biogas (m^3)	LPG (kg)
Cooking	2125.87	611.91	229.94	30.68	78.10	40.92
Water heating	334.06	393.14	30.37	46.02	8.78	0
Lighting	0	0	0	204.53	0	0
Space heating	596.69	477.59	173.54	0	0	0
Home appliances	0	0	0	230.10	0	0

tion per capita and annual growth rate in China rural areas were 131 kgce and 9.15% respectively and commercial energy consumption accounted for 30% of the total rural household energy consumption. Thus it is projected that in 2010 the average energy consumption per year per capita and per household are 619.79 kgce and 3098.95 kgce respectively).

(2) The structure of energy consumption of rural households in 2010 is the same as in 2007: straw (49%), firewood (28%), coal (14%), electricity (5%), biogas (2%), LPG (2%).
(3) The emission of CO_2 and SO_2 mainly results from straw and firewood. The emission reduced and land area saved because of the substitution of straw and firewood by biogas are equal to the emission amount of CO_2 and SO_2 and land area degraded when the two energy sources are used.
(4) The total cost of building and maintaining a biogas digester with an output of 385 m^3 and 20-year service life is 1600 yuan.
(5) One hour solar radiation is enough to raise the temperature of the water in a solar energy heater from 10 °C to 60 °C. If the suppliable energy of a heater is based on the formula $Q = cm(t_2 - t_1)$ and 1396 sunshine hours within a year, and the water capacity of a solar energy heater in the project is 130 L, then energy supplied by one unit of solar heater is 1300.35 kgce (1396Q/29308000 = 1300.35 kgce), and the unit price of solar energy heater with a 20-year service life is 3380 yuan.
(6) Energy supplied by a solar stove is 171.48 kgce and the unit price of solar stove with 20 year service life is 350 yuan.
(7) The conversion coefficients of straw, firewood, electricity, biogas and LPG to standard coal are: 1 kgce = 2 kg straw = 1.72 kg firewood = 3.3 kWh electricity = 1.4 biogas = 0.28 m^3 LPG.
(8) Unit prices of energy sources: straw (0.28 yuan/kg), firewood (0.34 yuan/kg), coal (0.75 yuan/kg), electricity (0.53 yuan/KWh), biogas (0.21 yuan/m^3 year), LPG (4.97 yuan/kg), solar heater (169 yuan/set year) and solar stove (23 yuan/set year).
(9) The costs of treating CO_2 and SO_2 are 0.00011 yuan/g and 0.000945 yuan/g respectively. The cost of recovering land degraded is 0.0336 yuan [8].

Table 2 shows the consumption of the six energy sources for five different purposes. The consumption of each energy source for a particular purpose is the total energy consumption of the rural household multiplied by the percentage of the energy source in total energy consumption and the percentage of the energy source in a particular use of energy. For example, the consumption of straw for cooking is 2125.87 kg (i.e., 619.79 kgce/person × 5 persons/household × 2 kg/kgce × 49% × 70%).

The total financial cost of energy consumption of each rural household can be obtained when the relevant data are put into in Formula (1):

When $i = 1, 2, \ldots, 6$, $j = 1$, $\sum_i^n c_i x_{ij} = 1211.78$ yuan;

When $i = 1, 2, \ldots, 6$, $j = 2$, $\sum_i^n c_i x_{ij} = 276.19$ yuan;

When $i = 1, 2, \ldots, 6$, $j = 3, 4, 5$, the results of $\sum_i^n c_i x_{ij}$ are 108.4 yuan, 459.33 yuan, 128.07 yuan respectively.

Therefore, $Tc = \sum_j^m \sum_i^n c_i x_{ij} = 2183.77$ yuan (1211.78 + 276.19 + 108.4 + 459.33 + 128.07 = 2183.77 yuan).

That is to say, under the present energy consumption structure, the total financial cost of energy consumption in each rural household in one year is 2183.77 yuan.

2.3. Environmental impacts of energy consumption of rural households

The environmental impacts of energy consumption of rural households include two aspects: one is the emission of greenhouse gasses such as CO_2 and SO_2; the other is the land degradation caused by collecting firewood. The three kinds of cost are converted into money. Thus, the total cost of environment Te can be calculated by the following formula:

$$Te = \sum_j^m \sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i) \quad (i = 1, 2, \ldots n, \; j = 1, 2, \ldots m) \tag{2}$$

where x_{ij} is the amount of the *ith* type of energy source to use for the *jth* type of purpose (in coal equivalents), P_1, P_2 and P_3 represent the environmental costs of emission of CO_2, SO_2 and vegetation degradation respectively. α_i, β_i and γ_i represent the costs of treating CO_2 and SO_2 and recovering land degradation respectively (in this paper, γ_i is supposed to be related with collection of firewood only).

Put the relevant data into $\sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i)$ in Formula (2) and sum up the results, the total environmental cost of energy consumption of each rural household is obtained:

When $j = 1$, $\sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i) = 630.13$ yuan;

When $j = 2$, $\sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i) = 240.78$ yuan;

When $j = 3, 4, 5$, the values of $\sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i)$ are 0 yuan, 338.76 yuan and 0 yuan respectively. Thus, the total environment cost of energy consumption of each household is 1209.67 yuan (630.13 + 240.78 +338.76 = 1209.67 yuan).

3. Cost-benefit simulations for utilizing rural renewable energy

3.1. Economic cost and benefit analysis

Suppose a biogas pit, a solar heater and a solar stove are built to replace straw, firewood, coal and LPG to supply the energy demanded for cooking, water heating (among which, biogas and solar stove are for both cooking and water heating, while solar heater is only for water heating) in the household. According to the energy consumption structure in Table 1, the total energy that are supposed to be supplied by the three renewable facilities is 2882.02 kgce [3098.95 × (49% + 28% + 2% + 14%)]. However, since the energy supplied by one unit of solar heater, solar stove and biogas are 1300.35 kgce, 171.48 kgce and 275 kgce respectively, the aggregat-

Table 3
Kilogram of coal equivalent supplied by energy sources for different purposes in rural households under the present consumption structure. Unit: kgce.

	Straw	Firewood	Coal	Electricity	Biogas	LPG
Cooking	1062.94	355.75	229.94	9.30	55.78	61.98
Water heating	167.03	234.28	30.37	13.95	6.20	0
Lighting	0	0	0	61.98	0	0
Space heating	288.51	277.67	173.54	0	0	0
Home appliances	0	0	0	69.73	0	0
Total	1518.47	867.70	433.84	154.95	61.98	61.98

Table 4
Emission amount of CO_2, SO_2 of and land degradation caused by energy sources.

	Straw (kg)	Firewood (kg)	Coal (kg)	Electricity (kwh)	Biogas (m^3)	LPG (kg)
CO_2 (α_i)	1341 g	1468 g	1487 g	0	1172.5 g	548.6 g
SO_2 (β_i)	0.44 g	0.32 g	13.4 g	0	0.63 g	0.296 g
Land degradation (γ_i)	0	1[a]	0	0	0	0

Source: [7].

[a] Land degradation results from the collection of firewood only.

ed energy supplied by these three facilities is only 1746.84 kgce. In other words, the renewable energy sources can only partly replace straw, firewood, coal and LPG for cooking and water heating.

As shown in Table 3, the energy supplied by straw, firewood and LPG for cooking in kilogram of coal equivalent is 1480.67 kgce (1062.94 + 355.75 + 61.98 = 1480.67 kgce), and the energy needed for water heating is 451.83 kgce (167.03 + 234.28 + 30.37 + 13.95 + 6.20 = 451.83 kgce). Thus we suppose that the solar heater undertakes all the task of water heating while the solar stove and biogas pit undertake the task of cooking, and the remaining energy needed for cooking is to be complemented by other sources.

The economic cost per household per year can be obtained when the data in Table 5 are put into Formula (1).

When $i = 1, 2, \ldots, 7, j = 1, \sum_i^n c_i x_{ij} = 885.27$ yuan;

When $i = 1, 2, \ldots, 7, j = 2, \sum_i^n c_i x_{ij} = 169$ yuan;

When $i = 1, 2, \ldots, 7, j = 3, 4, 5$, the value of $\sum_i^n c_i x_{ij}$ are 108.40 yuan, 459.33 yuan and 121.95 yuan respectively. The $Tc = \sum_j^m \sum_i^n c_i x_{ij} = 1743.95$ yuan (885.27 + 169 + 121.95 = 1743.95 yuan). In other words, the financial cost per household per year is 1743.95 yuan when the renewable energy sources are utilized to partly replace traditional energy sources and commercial energy sources.

The economic benefit of utilizing rural renewable energy is the average financial cost saved per household per year when comparing with the past, i.e., 439.82 yuan (2183.77–1743.95 = 439.82 yuan). Suppose interest rate is 5.31% per year, the present value of the total economic benefit within the next twenty years from 2011 to 2030 shall be 5563.72 yuan per household (Table 6).

3.2. Environmental cost and benefit analysis

Put the data in Table 4 and costs of treating CO_2 and SO_2 and recovering land degraded into Formula (2), the environmental cost for utilizing rural energy can be obtained.

When $j = 1, \sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i) = 371.37$ yuan;

When $j = 2, \sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i) = 0$ yuan;

When $j = 3, 4, 5$, the results of $\sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i)$ are 0 yuan, 338.86 yuan and 0 yuan respectively.

Thus, the value of $\sum_j^m \sum_i^n x_{ij}(P_1\alpha_i + P_2\beta_i + P_3\gamma_i)$ is 710.23 yuan (371.37 + 0 + 338.86 + 0 = 710.23 yuan).

In other words, the environmental cost per household per year for utilizing rural renewable energy is 710.23 yuan. So the

Table 5
Energy consumption structure after renewable energy sources are utilized.

Purpose	Biogas Pit (m^3)	Stove Heater (kgce)	Coal (kg)	Electricity (kwh)	Solar stove (kgce)	Straw (kg)	Firewood (kg)
Cooking	385	0	229.94	30.68	171.48	2116.81	0
Water heating	0	451.83	0	0	0	0	0
Lighting	0	0	0	204.53	0	0	0
Space heating	0	0	173.54	0	0	595.69	477.59
Home appliances	0	0	0	230.31	0	0	0

Table 6
Kilogram of coal equivalent supplied by energy sources for different purposes after renewable energy is utilized. Unit: kgce.

	Biogas pit	Solar heater	Coal	Electricity	Solar stove	Straw	Firewood
Cooking	275	0	229.94	9.30	171.48	1058.41	0
Water heating	0	451.83	0	0	0	0	0
Lighting	0	0	0	61.98	0	0	0
Space heating	0	0	173.54	0	0	297.85	277.67
Home appliances	0	0	0	69.73	0	0	0

environmental benefit of utilizing rural renewable energy is 499.44 yuan (1209.67–710.23 = 499.44 yuan) per household per year, which is the environmental cost saved when comparing with past. Similarly, if the interest rate is 5.31% per year, the present value of the total environmental benefit within the next 20 years from 2011 to 2030 shall be 6272.97 yuan per household.

4. Scaling up utilization of rural renewable energy

Rural renewable energy and energy efficiency are unique in that they require higher up-front investment than conventional energy sources, while at the same time providing multiple benefits that are not reflected in their cost. As previously noted, the up-front investment of the three renewable energy facilities is 5230 yuan (3380 yuan/solar heater + 1500 yuan/biogas pit + 350 yuan/solar stove). This is undoubtedly a large amount for Chinese farmers whose current income per capita is only about 4000 yuan. The poor usually cannot afford to bear the up-front costs of energy installations. Public support, incentive policies and innovative financing mechanisms are therefore needed to support the installation of renewable energy facilities in the rural households.

4.1. Public support and policy incentives

Public support is essential for scaling up the utilization of rural renewable energy. Without public support, the plan of utilizing rural renewable energy would be a castle in the air. Although the recognition of the significance of renewable energy is growing, most people including some policy makers, however, still do not fully understand the benefits that renewable energy can bring about and the feasibility of renewable energy projects. Continuous advocacy and campaign for promoting renewable energy is therefore crucial. One of the advocacy strategies is using media to amplify the message.

Policy incentives are of the utmost importance for scaling up the utilization of rural renewable energy. The most common government policies with respect to promoting the utilization of rural renewable energy are financial incentives and market support policies. Financial incentives include: (i) exemption of taxes and duties in producing and purchasing renewable energy facilities; (ii) provision of direct subsidies in the form of rebates; (iii) free installation of renewable energy facilities [9,10]. Market support policies include training, information and technical assistance to users and other programs that remove investment barriers.

4.2. Innovating financing mechanisms

Appropriate financing mechanism has a major role to play in the promotion of rural renewable energy. While conventional financial instruments such as capital subsidies, donor grants, tax rebates and similar fiscal incentives are able to achieve a certain level of penetration, the large-scale use of renewable energy products requires innovative approaches to the selection and delivery of financial instruments and channels. The following are some of innovative financial models that can be adopted.

4.2.1. Clean development mechanism (CDM)

Clean development mechanism (CDM) is one of the Kyoto mechanisms to achieve the objective of reducing GHG emissions. CDM allows emission reduction projects that assist in creating sustainable development in developing countries to generate "certified emission reductions (CER)" for use by the investor. It enables Annex-1 countries (developed countries) to meet their emission reduction commitments in a flexible and cost-effective manner. CDM assists developing countries (non-Annex I or also called the "host countries") in meeting their sustainable development objectives. Investors benefit from the CDM by obtaining Certificates of Emissions Reductions. Host countries benefit in the form of investment, access to better technology, and local sustainable development.

4.2.2. Consumer credit model

In this mechanism, local finance institutions provide loans to users to buy the renewable energy facility. The renewable energy enterprise in this case transacts on commercial basis with the users.

4.2.3. Revolving fund

A revolving fund is a reserve money or fund which is lent by any number of organizations. It is used for lending to one or more borrowers. Usually, an additional sum is charged (interest) to the borrower that acts as a fee for providing the service (administrative costs) and helps to protect the fund from being depleted. These include inflation, non-payments and the cost to the lender of getting outside finance.

5. Concluding remarks

Developing rural renewable energy provides the rural poor with sustainable rural energy service at reasonable cost while at the same time preventing further environmental degradation. There exists a strong nexus between energy and sustainable rural development, as energy is a basic input in almost all economic development and social activities. Therefore, there is a need for developing, planning, and implementing an integrated rural development strategy to cater to the needs of rural population.

Dissemination of information on the available rural renewable energy technologies is critical. Rural customers should be able to choose from a number of energy options, and they may find a hybrid solution most appropriate. Solar water heating, PV panels for electricity, biomass, mini- and micro-hydro power generators, and wind turbines are some of the typical options. Without reliable accessible information in their own language, these consumers will not be able to make informed choices about the technologies that they want to use. Furthermore, available innovative financing mechanisms need to be explained, along with the advantages and disadvantages they inherit.

References

[1] Asian Development Bank. China: Integrated Renewable Biomass Energy Development Sector Project ADB; 2009.
[2] Bassam NE, Maegaard P. Integrated Renewable Energy for Rural Communities: Planning Guidelines, Technologies and Application. Elsevier Science; 2004.
[3] Cecelski E. Enabling equitable access to rural electrification: current thinking on energy, poverty and gender. Washington, DC: World Bank; 2000.
[4] Khim (UNDP) L. Rural energy for poverty reduction: good practice and lessons learned from UNDP; 2009, Available from http://www.esmap.org/sme/Lay_Khim.pdf.
[5] Center for Entrepreneurship in International Health and Development School of Public Health University of California, Berkeley. PARTNERSHIP FOR CLEAN INDOOR AIR, Household Energy, Indoor Air Pollution and Health: Overview of Experiences and Lessons in China; 2005.
[6] Zhang P-d, Jia G, Wang G. Contribution to emission reduction of CO_2 and SO_2, by household biogas construction in rural China. Renewable and Sustainable Energy Reviews 2007;11:1903–12.
[7] Wang X, Hu Y, Dia X, Zhoa Y. Analysis and simulation on rural energy–economy system on Shouyang County in China. Renewable and Sustainable Energy Reviews 2006;10:139–51.
[8] Guozhu L, et al. Assessment of environmental and economic costs of rural household energy consumption in Loess Hilly Region. Gansu Province, China. Renewable Energy 2009;34:1438–44.
[9] Huang L. Financing rural renewable energy: a comparison between China and India. Renewable and Sustainable Energy Reviews 2009;13:1096–103.

[10] Canadian Renewable Energy Alliance, Financing Sources and Mechanisms for Renewable Energy and Energy Efficiency. www.canrea.ca/pdf/CanREAFinancingPaper.pdf.
[11] Long S. Approaches to using renewable energy in rural areas of China. www.springerlink.com/index/n003076123x53.
[12] Zhou Z, Wu W, Wang X, Chen Q, Wang O. Analysis of changes in the structure of rural household energy consumption in northern China: a case study. Renewable and Sustainable Energy Reviews 2009;13(1): 187–93.
[13] Yutaka T, Liu J, Kondou Y, Ning Y, Fukasawa O. A survey on energy consumption in rural households in the fringes of Xian city. Energy and Buildings 2006;38:1335–42.